Is there a statistical association between Ferns and Garlic Mustard (*Alliaria petiolata*) in forest stands along the Niagara Escarpment?

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Abstract

*One major factor affecting native plant species in southern Ontario seems to be the invasion of forest floors by alien plant species such as garlic mustard (*Alliaria petiolata*). However, Garlic mustard now appears to have affected sensitive, even fragile, ecosystems that we should preserve. Ferns once dominated the ecosystem in southern Ontario. Personal observation – along with other reference work – suggests that they are disappearing. It has been hypothesized that there is a statistical association ($p \leq 0.5$) between ferns and garlic mustard on the Niagara Escarpment in Ontario Canada. Subsequently, it was theorised that the decrease in the distribution of ferns on the Escarpment is a result of garlic mustard proliferation. To test this hypothesis, data were collected concerning the presence or absence of ferns and garlic mustard during the months of May, June and July 2005 using the Bruce Trail and other side trails as transects, covering a total trail distance of 12.6 kilometres. The study targeted all known fern species found in the escarpment's forests. Random points were selected on either side of the trails and the presence or absence of both taxa were noted using a $1m^2$ quadrat. The results revealed that there is a significant statistical relationship between the two taxa ($X^2 = 8.2$; $df = 1$; $p = 0.004$). A coefficient of association (V) value of -0.14 revealed the association to be negative. The negative association clearly identifies garlic mustard as one plausible factor affecting ferns on the escarpment. The results have far reaching implications regarding biodiversity conservation on the escarpment, as different conservation groups manage these forest stand areas. It likewise indicates that systems once considered undisturbed might be impacted negatively by several factors including this invasive plant.*

Introduction

Ferns were once abundant in southern Ontario. Preliminary observation suggests that they are disappearing from the ecosystems where they once proliferated. One area in southern Ontario that had an abundance of ferns is the Niagara

Escarpment. Field observations supported the notion that there is a decrease in the distribution and abundance of these plant species from this ecosystem. The decline may be attributed to changes in the environmental conditions, fragmentation and disturbance factors. Change in environmental and or ecological conditions often predisposes a site to invasion by opportunistic plant species. Garlic mustard (*Alliaria petiolata*) is one such plant species that now thrives on the Escarpment.

Anderson *et al* (1996) noted that garlic mustard is an exotic plant species that has invaded woodlands in several areas in midwestern and northeastern United States and Canada, where it is displacing the indigenous understory flora. Examples of such invasion can be seen on the forest floor in conservation areas throughout the Niagara Region.

Havinga *et al* (2000) listed garlic mustard as an invasive plant that required attention in southern Ontario and Bowers (2002) suggested that a statistical relationship might exist between the distribution of garlic mustard (*Alliaria petiolata)* and fern populations on the Niagara Escarpment. The purpose of this study was to ascertain whether a statistical association exists between garlic mustard and ferns.

Methods and Materials

Study areas

The seven areas used in this study were Balls Fall's, Louth Conservation Area, Short Hills Park, DeCew Falls, Woodend Conservation Area, Queenston Heights, and Niagara Glen. All sites are on the Niagara Escarpment a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Biosphere Reserve and appear to have different levels of disturbance. The forests comprise a variety of tree species at different successional stages. These sites have various recreational trail types. The trails vary from paved areas allowing access to motorized vehicles to steep rugged terrains. The Bruce Trail is the major recreational trail. The main trails cover a distance of over 850km. Riley *et al* (1996) noted that these seven forests are recognised as Areas of Natural and Scientific Interests (ANSI's). The areas are managed by three different organizations: Niagara Parks Commission, Niagara Peninsula Conservation Authority and the Ministry of Natural Resources. Figure 1 provides the location of the study sites. Garlic mustard has been recorded along sections of the Bruce Trail (Bowers, 2002; L'Ecuyer-Engelen, 2002) in some of the locations where this study was conducted.

L'Ecuyer-Engelen (2002) identified six different fern species along the trail demonstrating that ferns still inhabit the area. The focus of this study was on fern species found adjacent to the recreational trails.

All data collection was done to ensure minimal damage to habitat, existing ferns or other native species. No live plant specimens were removed from any of the study sites. Personal experience and Blossey (2003) have revealed that humans act as vectors to transferring seeds. Data were collected on different days thereby limiting the possibility of transferring foreign species from one area to another.

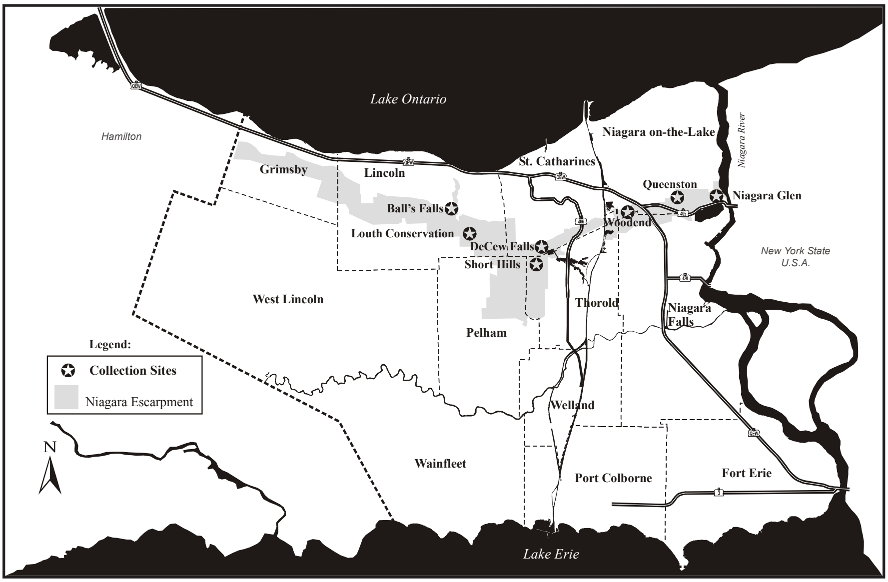
Methods

Data were collected at the seven sites using the Bruce and side trails as transects. Collection started where there was full leaf canopy and began with the first fern specimen encountered in Section 1 after entering the designated trails. Fern specimens used for decorative purposes (e.g. planted at the entrance to respective sites) were not considered part of this study. Random distances were selected along the trails to determine individual collection points.

Access to each collection point was perpendicular to the trails and aided in reducing undue site disturbances.

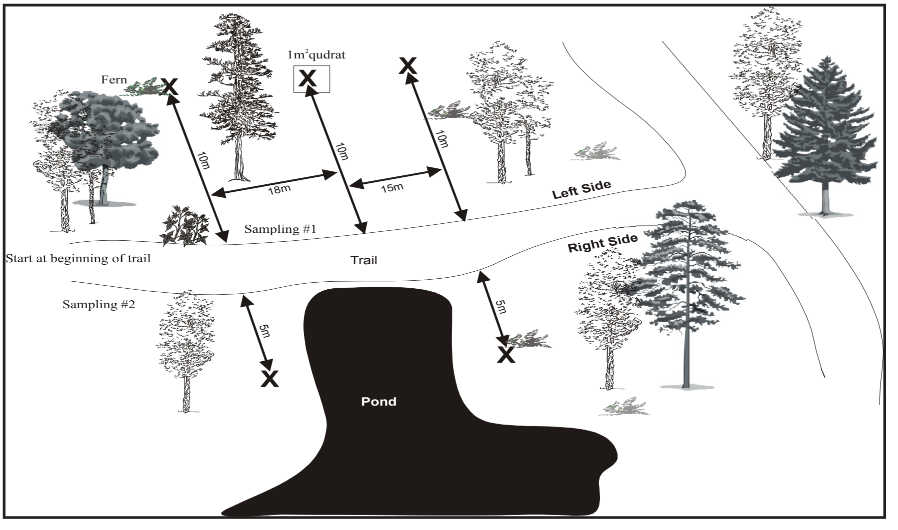
The study sites were divided into two sections. Section 1, which comprised the areas left of the designated trails and Section 2 comprised of the areas right of the same trails. Data were collected 10 metres from the trail in Section 1. Points 10 metres from the trails were considered to have lower levels of disturbance and likely provided more suitable growth conditions for ferns. It was theorized that these areas would be least impacted by garlic mustard. Data were then collected directly opposite of Section 1 in Section 2. Collection points here were 5 metres from the trails. It was felt this area would have a higher level of disturbance

Figure 1. Map of Niagara Region showing sections of the Niagara Escarpment and the location of the seven study sites.



when compared with Section 1 and that garlic mustard would be more abundant closer to the trails (Shimp, 2002). Where areas were inaccessible due to rivers, slopes or any other physical barriers, the next random point along the trail was selected and used instead. Figure 2 provides a representation of the sampling technique.

Figure 2. Data Collection Outline of the sampling technique used in collecting data on respective trails



Data Collection

Data were collected using $1m^2$ quadrats. Two random number tables were used to choose the collection points along each transect. The mean distance between collection points was 15 metres**.** The total number of sampled points for each site ranged from 64-83.

A minimum of five individual sampled points with fern species recorded per site was considered adequate for evaluation. This number of individual fern species per site was selected to standardize the results. It was felt that if the site did not support a viable fern population then the results would not reflect the true association between the ferns and garlic mustard.

The data were collected in the months of May, June and July (2005) when all fern species were in their active growth stages. The trees had full canopy at the time of collection. Canopy cover is considered essential as most fern species in this study could be considered as forest species requiring some shade for optimal growth. The collected data were then entered into a 2X2 contingency table from which they were analysed (Table 1).

Table 1 Method for analysing collected data

	Garlic Mustard	
Fern Species	Present	Absent
Present		
Absent		

(Modified from Sokal and Rohlf, 1981)

Results

The study recorded 14 different fern species at the sites. Table 2 shows the total number of fern species found for each site. Data were collected from 572 points along 12.6 kilometres of main and side trails. Fourteen different fern species were identified as compared to the 31 species recorded in the same areas by Riley *et al.* (1996). (Note that Riley *et al*. used systematic searches rather than random sampling). Sensitive fern (*Onoclea sensibilis*) was found at DeCew Falls but was not found by Riley *et al* (1996).

Site-by-site and grouped analyses were done to determine the statistical association between ferns and garlic mustard. Five sites from the data collection met the criteria of having a minimum of five sampling points with ferns. Two combined site analyses were done, the first excluding Queenston and Woodend

Table 2. UTM references and the number of fern species identified in the seven study sites.

Forest	UTM References	Collection Dates	# of species found by Lyons	# of species recorded by Riley *et al*(1996)	Garlic Mustard Present
Niagara Glen	570 760	2005-05-23	7	22	Yes
Queenston	575 800	2005-06-22 2005-06-17	2	8	Yes
Woodend	500 790	2005-05-21	2	5	Yes
DeCew Falls	405 745	20050-6-04	6	11	Yes
Short Hills	395 730	2005-06-22	4	19	Yes
Louth Conservation	358 750	2005-07-01	3	18	Yes
Ball's Falls	320 780	2005-07-03	7	16	Yes

Modified from Williams-Linera et al 2005

Conservation Area where few or no ferns were found, and the other including these two areas. The outcome of these analyses changed the results only marginally.

The analysis was done on the right and left side of the trails, and then combined for individual sites. Tables 3 and 4 show the results. Table 3 shows that there is no statistical association between the two taxa at any site taken by itself. Table 3 shows the p and V-values for individual sites. By contrast, Table 4 shows a statistically significant relationship between the two taxa when all the sites were combined. Table 4 shows the p and V- value from the analysed data for the five sampling sites and then all sites.

The results here are significant with p-values of 0.004 and 0.001 for five sites and all sites respectively. These values revealed a strong statistical association between garlic mustard and fern species on the escarpment. The combined analysis revealed that there is a weak negative association between the two taxa (V= -0.14).

Garlic mustard was abundant at all the sites. Vast monocultures existed. Figure 3, taken at Woodend, is one example of the monoculture.

Table 3. Statistical analyses for individual sites

	Left side	Right side	Site Combined	
Sites	p-value	p-value	p-value	V-value
Niagara Glen	0.921	0.577	0.067	+0.06
Queenston	0.706	0.746	0.565	+0.07
Woodend	0.212	0.402	0.704	+0.04
Short Hills	0.845	0.834	0.483	-0.01
DeCew Falls	0.845	0.350	0.403	-0.1
Louth Conservation	0.011	0.975	0.079	-0.19
Ball's Falls	0.424	0.121	0.079	-0.19

Table 4. Statistical analyses for all sites combined

5 sites (Excluding Woodend and Queenston)	p -values	V- value
Left side	0.04	-0.14
Right side	0.066	-0.17
Sites combined	0.004	-0.14
Data from the 7 sites		
Left side	0.008	-0.16
Right Side	0.074	-0.11
Sites combined	0.001	-0.14

Figure 3. Large monocultures of garlic mustard at Woodend

Discussion

The results from this study on the seven forest stands provide evidence that there is a negative statistical association between ferns and garlic mustard. (Table 4 p= 0.004 and V = -0.14.) This allowed for the rejection of the null hypothesis that there is no statistically significant association between garlic mustard and fern species.

The results from this study have clearly identified garlic mustard as a plausible factor affecting ferns (V = -0.14). There are clearly other factors impacting ferns on the escarpment. These factors may include: the trails, climatic conditions, fragmentation, human collection, and air pollution.

Both the raw and processed data indicate that ferns were not abundant at any of the sites, and that there was no statistical association between ferns and garlic mustard at the individual sites (Table 4). Of the 31 species recorded by Riley *et al* (1996) 14 were found in this study. This represents 45% of the known fern species within the study areas.

The data collection techniques used in this study differed from those of Riley *et al* (1996) who surveyed specific sites during their study that had been known since the 1970s or earlier, many of them as International Biological Program (IBP) sites or significant natural areas. Because of the different techniques used, it is not possible to make a direct comparison of the number of species identified in these studies.

Fern distribution at these sites should still be of concern. Comments made by Lewis (1991) suggest that ferns were so abundant once, that they were easily observed upon visiting the different sites on the escarpment. While this study did not include vegetative surveys, the findings are noteworthy as they support previous observations that the fern species are disappearing from the frontier they once occupied in profusion (Lewis 1991).

Conclusion

The study on the Escarpment revealed that there is a statistically significant negative association between fern species and garlic mustard. Garlic mustard was clearly identified as a plausible factor affecting ferns on the Niagara Escarpment. Studies should now be conducted to identify the other factors affecting ferns.

To effectively address the problem, management efforts must represent a collective approach by the various bodies that are responsible for the individual conservation sites to protect native ferns from the effects of garlic mustard and other relevant factors currently impacting their distribution and abundance.

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